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## Mathematical Formalization of the Economic Sustainable Development Institute in the Context of the National Economy Competitiveness

Valeriia Kasianova  1\*

<sup>1</sup> Odesa I. I. Mechnikov National University (Ukraine). Associate Professor at the Department of Economics and Entrepreneurship, Candidate of Physical and Mathematical Sciences, Associate Professor.

\* **Corresponding Author**, e-mail: [v.kasianova@onu.edu.ua](mailto:v.kasianova@onu.edu.ua)

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### ABSTRACT

The article examines the mathematical formalization problem of the state institutional potential in conditions of military crisis and the tasks of post-war reconstruction of Ukraine. The relevance of the work is due to the growing role of sustainable development institutions, the need to align strategic goals with current management decisions, and the lack of a unified approach to interpreting the concepts of “sustainable development” and “economic institute of sustainable development”. It is shown that existing approaches to assessing institutional potential mainly focus on its individual components, use qualitative or semi-quantitative methods and contain several methodological limitations related to the subjectivity of expert assessments, the heterogeneity of indicators and the insufficient justification of the weighting factors’ choice. The research aims to develop a mathematical formalization of institutional potential with an emphasis on economic institutions of sustainable development. To this end, the structure of institutional potential was analyzed, existing models of its measurement were critically evaluated, and an improved approach to describing the mechanism of governance institution functioning was proposed. The paper argues that the economic environment should be considered as a highly complex system within which macroeconomic, social, political, and behavioral factors interact, and in wartime, these relationships become even more unstable. Based on a systems approach, a mathematical scheme for assessing competitiveness in a multidimensional space of factors and determining the optimum zone of the objective function is proposed. A step-by-step transition from the current state to the optimal one is formalized through iterative management of impact parameters and minimization of resource costs within the institutional mechanism. It is emphasized that the practical implementation of the model requires constant adjustment due to the variability of priorities, the instability of influencing factors, and the dynamics of military risks. It is concluded that the effective use of Ukraine’s institutional potential is possible only under the conditions of further development of theoretical foundations, improvement of the regulatory framework and constant updating of mathematical models of institutional management.

### KEYWORDS

sustainable development institutes, mathematical formalization, national economy, sustainable development, competitiveness.





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# СОЦІАЛЬНИЙ РОЗВИТОК: економіко-правові проблеми

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## Математична формалізація економічного інституту сталого розвитку в контексті конкурентоспроможності національної економіки

Валерія А. Касьянова  <sup>1</sup> \*

<sup>1</sup> Одеський національний університет імені І.І. Мечникова (Україна). Доцент кафедри економіки та підприємництва, канд. фіз.-мат. наук, доцент.

\* Автор-кореспондент, e-mail: [v.kasianova@onu.edu.ua](mailto:v.kasianova@onu.edu.ua)

### СТАТТЯ

### АНОТАЦІЯ

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У статті досліджено проблему математичної формалізації інституційного потенціалу держави в умовах воєнної кризи та завдань післявоєнного відновлення України. Актуальність роботи зумовлена зростанням ролі інститутів сталого розвитку, необхідністю узгодження стратегічних цілей із поточними управлінськими рішеннями та браком єдиного підходу до трактування понять «сталий розвиток» і «економічний інститут сталого розвитку». Показано, що наявні підходи до оцінювання інституційного потенціалу переважно зосереджуються на окремих його складових, використовують якісні або напівкількісні методи та містять низку методологічних обмежень, пов'язаних із суб'єктивністю експертних оцінок, різномірністю показників і недостатньою обґрунтованістю вибору вагових коефіцієнтів. Метою дослідження є розроблення математичної формалізації інституційного потенціалу з акцентом на економічні інститути сталого розвитку. Для цього проаналізовано структуру інституційного потенціалу, критично оцінено існуючі моделі його вимірювання та запропоновано удосконалений підхід до опису механізму функціонування інституту управління. У роботі обґрунтовано, що економічне середовище слід розглядати як надскладну систему, у межах якої взаємодіють макроекономічні, соціальні, політичні та поведінкові фактори, а за умов війни ці взаємозв'язки стають ще більш нестабільними. На основі системного підходу запропоновано математичну схему оцінювання конкурентоспроможності в багатовимірному просторі факторів та визначення зони оптимуму цільової функції. Формалізовано покроковий перехід від поточного стану до оптимального через ітераційне управління параметрами впливу та мінімізацію ресурсних витрат у межах інституційного механізму. Підкреслено, що практична реалізація моделі потребує постійного коригування через змінність пріоритетів, нестійкість факторів впливу та динаміку воєнних ризиків. Зроблено висновок, що ефективне використання інституційного потенціалу України можливе лише за умов подальшого розвитку теоретичних засад, удосконалення нормативно-правової бази та постійного оновлення математичних моделей інституційного управління.

### КЛЮЧОВІ СЛОВА

інститути сталого розвитку, математична формалізація, національна економіка, сталий розвиток, конкурентоспроможність.



## 1. Introduction

When solving economic problems, one often has to resort to mathematical methods and models [13]. One such problem is the issue of the institutional capacity of the state [11; 15]. In connection with Ukraine's accession to the Global Initiative for the Implementation of the UN Sustainable Development Goals, regulatory, financial, economic, and information and communication institutions were specified at the legislative level [9; 6]. However, there is still no consistency in the interpretation of the concepts of "sustainable development", "institution", "institutional potential", and "economic institute of sustainable development" [10]. The war and the crisis caused by it not only worsened macroeconomic indicators and social conditions, but also exacerbated the structural imbalance of sustainable development institutions and complicated the functioning of the institutional potential mechanism [5; 2]. There is also a need to reform established institutions and introduce new ones into the management structure, which, in particular, confirms the decisions of the country's leadership to merge and separate ministries and other institutional structures in recent years [4; 8]. The threats of war and the impacts of the crisis are deepening the gap between agreed and standardized strategies for sustainable development and operational management decisions taken to address urgent and critical problems [5; 2; 14]. This increases the imbalance in achieving goals, interferes with the resolution of the tasks facing sustainable development institutions, and hinders the use of opportunities that are conditioned by the ability to realize the country's institutional potential [7; 3].

## 2. Literature Review

In the scientific literature, there are various approaches to the mathematical formalization of the institutional potential of the state. Scientists have pointed out the urgent need for such formalization in its integral meaning many times, but have focused their efforts mainly on assessing the components of institutional potential, primarily the economic and investment component [12; 11; 15]. Also, qualitative rather than quantitative assessment methods were mainly used [7; 13; 3].

In our opinion, the disagreements in scientific works were caused by significant conceptual uncertainty in the understanding of the institutional potential of the state, which led to the lack of relevant methodological support for its quantitative assessment. This is confirmed in the article Soldak [15, p. 31], which states that assessing the level of institutional potential must necessarily be based on "the development of new approaches to determining the essence, structures and methods of assessment" of the specified scientific category, since this is because the importance of "the influence of institutions as incentives and constraints" on economic processes is generally recognized [15, p. 31]. In particular, in the mentioned study [15], and some other scientific works, an index method is proposed. Analysis of this method identified the following inconsistencies. Each of the indicated groups of indicators, and even indicators of the same group, may have different units of measurement – monetary, in points, as shares or percentages of the total volume, etc. In this case, using an additive approach, which assumes a single measurement scale, is erroneous. Determining weight by the expert method introduces the subjectivity of expert judgments into mathematical formalization. The calculation of weighting coefficients based on their correlation with one of the macroeconomic indicators, in particular gross domestic product per capita [15, p. 39] is not sufficiently justified, since the choice of the macroeconomic indicator is also subjective. It is also not sufficiently clear how groups of indicators describing the "activity of development institutions" are formed [15, c. 46]. It is not specified how their weights are calculated, as these indicators may not be directly related to gross domestic product per capita or other macroeconomic indicators.

In the article [7, p. 117] a "scoring" system for assessing institutional potential is proposed. The use of a single unit of measurement for all groups of indicators in a point evaluation system allows to resolve certain controversial points of the Soldak approach [15, p. 37], but this does not exclude the subjectivity of expert assessments in determining the number of points for individual groups. At the same time, the analysis of the approach proposed in the article by Melnyk [7, p. 117], points to another problem, also characteristic of the approach by Soldak [15] – a single mathematical approach for evaluating factors, which, given the number of influencing factors and their multifaceted nature, is

actually impossible, since the factors can have a different mathematical nature – be stochastic, fuzzy or even indefinite.

### **3. Problem Statement**

The purpose of this study is to mathematically formalize institutional potential. To achieve this goal, the following tasks will be performed: the composition and structure of institutional potential are investigated; the main shortcomings of existing mathematical formalizations are analyzed; recommendations are developed that allow improving the formalization of institutional potential in the context of economic institutions of sustainable development.

### **4. Methods and Materials**

The methodology of mathematical formalization is based on a combination of scientific, quantitative and qualitative analysis. Based on a scientific review of the literature, problematic aspects were identified in the definitions of the concepts of “sustainable development” and “institutional capacity”. The use of actual data became the basis for improving the mathematical formalization of the problem of implementing institutional potential, in terms of the economic institute of state competitiveness.

### **5. Results and Discussion**

The economic environment is a very complex system that, in turn, is part of the country's integrated institutional system. This environment, in addition to multi-vector macroeconomic, social, and political influences, is determined by factors conditioned by economic agents, society, and individuals.

In conditions of war, radical changes are needed in the functioning of all institutions of sustainable development – from reviewing the principles of organizing social and political activity, rethinking economic policy, to a significant transformation of business activity, the social sphere and their mechanisms. This, in turn, requires a transformation of the management of economic processes both during the period of martial law and in view of the prospects for post-war recovery.

To solve the problem of institutional regulation of the economic environment during this period, it is necessary to ensure:

- strengthening the coordination of public administration components for the rational use of the mechanism for implementing institutional potential;
- an effective system of inter-industry communication;
- smooth functioning of the mechanisms for providing resources to the economy;
- formation of a complex of mutually agreed institutional structures that allow for proper regulation of economic processes.

Economic institutions form the basis of the institutional environment for effective interaction of economic agents and ensure the balancing of the interests of all economic agents to direct their activities towards the implementation of the strategic national goal – sustainable development.

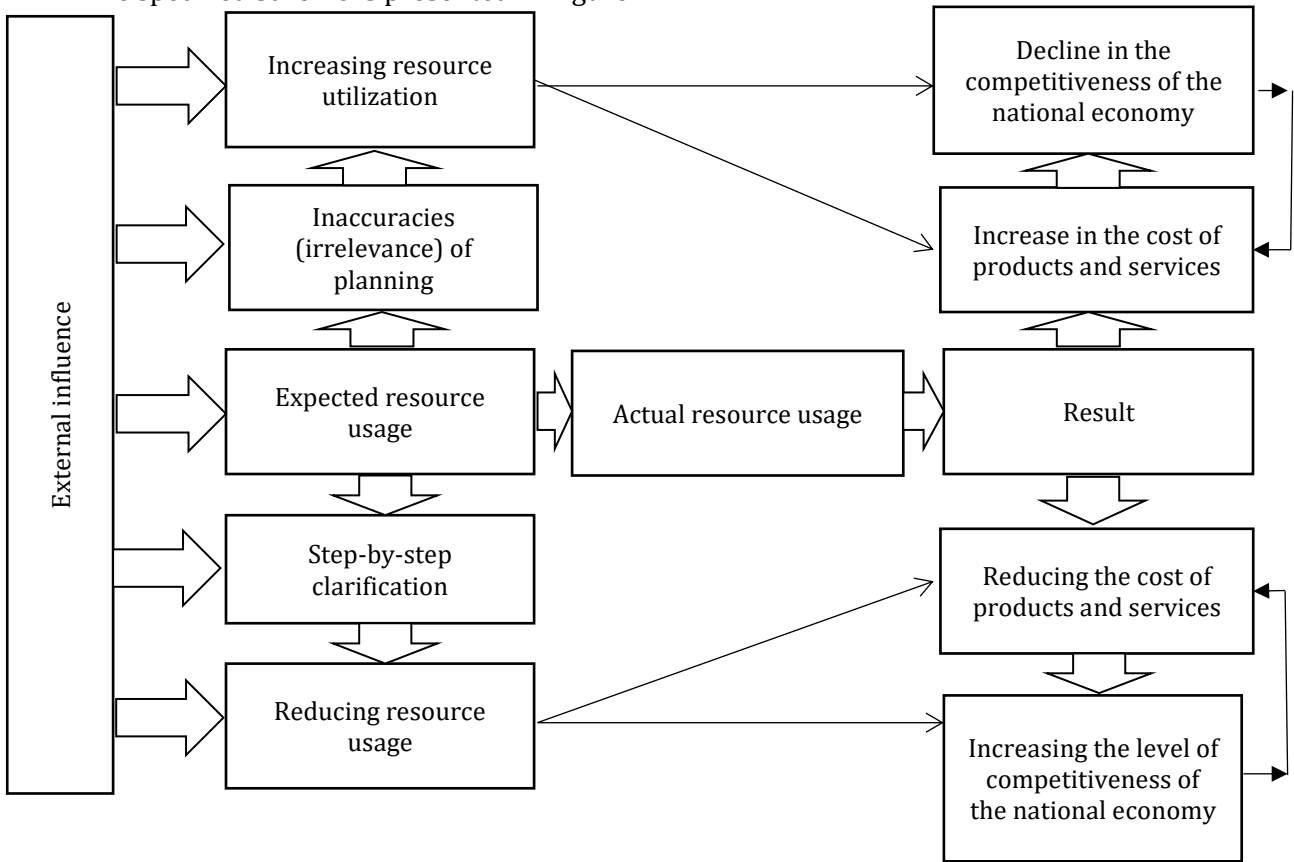
National economic institutions of sustainable development are entrusted with the task of institutional regulation, for which various tools and mechanisms are used: taxes, subsidies, state budgeting, loans, discount rate, etc. But the ontological basis of this is national characteristics, established traditions, archetypes, which, even after the transformation of institutions, determine their action and the choice of a model of social development.

At the same time, not only to ensure sustainable development, but also for the functioning of the economy, it is urgent to increase the country's competitive potential. In view of the above, it is important to create institutional conditions and ensure an effective institutional structure for the formation of a mechanism for the restoration and development of competitive potential.

To determine the strategic priorities of resource provision of competitive potential under the conditions of optimizing the actions of the institution of governance as a component of institutional support for sustainable development, the following mathematical formalization is proposed, which was

preceded by the development of a generalized scheme for using the institution of governance to increase the country’s competitiveness in the context of the mechanism of functioning of institutional potential.

The specified scheme is presented in Figure 1.



**Figure 1. Using the institution of governance to increase the country’s economic competitiveness in the context of the mechanism of functioning of institutional potential**

Source: Built by the author based on [3; 4; 6; 11; 15].

The mathematical expression of this problem can be presented as follows.

Objective function response surface ( $\Psi$ ) competitiveness in the multidimensional space of indicators of economic, social, and environmental activity in the context of the mechanism of functioning of institutional potential is formalized as a closed subset.

The optimum zone of the objective function response surface, towards the achievement of which the management measures of the entire set of state sustainable development institutions should be aimed, is defined as a matrix of factor values vector located in the sphere of management of individual institutions:

$$\langle \Delta x_1, \Delta x_2, \Delta x_3 \dots \Delta x_n \rangle = \begin{pmatrix} \Psi_{1opt} \\ \Psi_{2opt} \\ \Psi_{3opt} \\ \dots \\ \Psi_{mopt} \end{pmatrix}, \tag{1}$$

where  $\Delta x_1, \Delta x_2, \Delta x_3 \dots \Delta x_n$  are the coordinate intervals on the response surface of the objective function that define its optimum zone;  $\Psi_{1opt}, \Psi_{2opt}, \Psi_{3opt}, \Psi_{mopt}$  are the value of the factor vectors that are in the sphere of management of individual institutions;  $i = 1, 2, 3, \dots, n$  is the index of the corresponding coordinate;  $j=1, 2, 3, \dots, m$  is the individual institute index.

Coordinates of a point on the response surface that corresponds to the current state of competitiveness:

$$\langle x_1^*, x_2^*, x_3^* \dots x_i^* \rangle = \begin{bmatrix} \Psi_1^* \\ \Psi_2^* \\ \Psi_3^* \\ \dots \\ \Psi_j^* \end{bmatrix}, \quad (2)$$

where  $x_1^*, x_2^*, x_3^* \dots x_n^*$  are the coordinates of the point that determines the current national economy competitiveness state;  $\Psi_1^*, \Psi_2^*, \Psi_3^*, \Psi_m^*$ , are the current values of factor vectors that are within the control of individual institutions.

The next stage is the step-by-step finding of the most appropriate path from the point that determines the current state of the national economy's competitiveness in the context of the institutional potential functioning mechanism, to the objective function optimum zone.

This stage is mathematically formalized by the following equation:

$$\Psi^1 = \Psi_0(x_1, x_2, x_3 \dots x_{n-1}) + \sum_{z=1}^p \omega_z * \beta_z(x_1, x_2, x_3 \dots x_{n-1}), \quad (3)$$

where  $\Psi_0$  is a previous value of the objective function;  $\Psi^1$  is a next value of the objective function;  $\omega_z$  is a form-factor, which determines additional sets of parameters;  $\beta_z$  is a perturbation function;  $z = 1, 2, 3, \dots, p$  is the index that defines each iteration step.

The perturbation function is formalized by the following equation:

$$\beta_z(x_1, x_2, x_3 \dots x_{n-1}) = \begin{cases} \beta_z = +/\- \Delta\Psi \text{ if } \beta_z \geq \alpha \\ \beta_z = 0 \text{ if } \beta_z < \alpha \end{cases}, \quad (4)$$

where  $\Delta\Psi$  is the integral change of the objective function;  $\alpha$  is the threshold value of the perturbation function.

Operational management of the institutional potential use should be considered as a vector minimization  $\vec{\eta}$ , whose components are a set of individual resources, or, in a generalized sense, components of the mechanism for the institutional potential functioning  $\eta_1, \eta_2 \dots \eta_\lambda$ :

$$\vec{\eta} = \begin{bmatrix} \eta_1 \\ \eta_2 \\ \dots \\ \eta_\lambda \end{bmatrix} \rightarrow \min. \quad (5)$$

While the management tools for the economic support of the state's competitiveness in the context of the institutional potential functioning mechanism should consider the factors influencing the components of the vector  $\vec{\eta}$ .

At the same time, it should be noted that the practical application of this mathematical model is complicated at this time. This is due not only to the fact that the trends of traditional factors that influence the objective function of competitiveness under current conditions have breaks characterized by a change in the sign of their first derivative, but also to the fact that even sets of influencing factors change due to the dynamics of threats. Moreover, the weight of these influencing factors may undergo such changes that secondary factors become more significant than those that were fundamental in macroeconomic analysis.

## 6. Conclusions

Therefore, to use all the possibilities of Ukraine's institutional potential, it is necessary to improve the theoretical aspects of institutional potential, and as a consequence, the regulatory framework and management of institutions.

In order to avoid duplication of functions and tasks of institutions, it is proposed to resort to the mathematical formalization of sustainable development institutions, using the example of economic institutions of sustainable development, and more specifically, the formalization of the competitiveness management institute.

However, one should not forget that the process of mathematical formalization and modeling is cyclical. Also, taking into account the existing military threat and the rapid change in the values of sustainable development institutions' indicators work, the relevant mathematical models should be constantly improved, which will allow for their optimal use for the post-war restoration of Ukraine.

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